#6

4.2.2.2.3 The functional requirements of a flexible pipe flowline are generally the same as for a steel pipe flowline. As significant dynamic loading or motions are generally not experienced, the flexibility properties of flexible pipe simplify the project transport and installation phases.

4.2.2.3 Dynamic Applications

4.2.2.3.1 Dynamic applications use flexible pipe between supply and delivery points where there is relative movement between these two points while in service. These types of applications usually involve an offshore floating production facility or terminal connected to another floating facility, fixed structure, or fixed base (see Figure 3). Examples of dynamic applications include the following:

a. Flexible pipe risers for offshore loading systems.

b. Flexible pipe riser connections between floating production facilities and subsea equipment.

4.2.2.3.2 The riser configurations typically used are shown schematically in Figure 4. Note in general the critical sections in the riser configurations are at the top (or bottom), where there are high tensile forces (and large curvatures): at the sag bend, where there is large curvature (at low tension); and at the hog of a wave buoyancy section, where there is large curvature (at low tension).

4.2.2.3.3 The present dynamic applications of flexible pipes have only been for the production phase. However, with the advent of down hole motors, flexibles may also be used as drilling risers [5].

4.2.2.3.4 In addition to riser systems that use flexible pipe throughout, systems that combine flexible pipe and rigid pipe in the flow path have been used. Described as hybrid riser systems, they typically use a lower rigid riser section (such as a free standing riser) and an upper flexible pipe section (jumper line).

4.2.2.4 Jumper Lines

4.2.2.4.1 In addition to flowlines and risers, jumper lines, a further category, may be used for either static or dynamic applications. Examples of flexible pipes used in jumper line applications include the following (see also Figure 5):

a. Static Application.
   1. Intra-field connection of wellheads and manifolds (typically in lengths less than 100 meters).
   2. Connection of topside wellheads and platform piping on TLPs.

b. Dynamic Applications.
   1. Connection of wellhead platforms and floating support vessels.
   2. Lines in FPSO turret motion transfer systems.

4.2.2.4.2 The functions of the dynamic jumper lines (excluding internal turret lines) are in many respects similar to riser systems. Their operation, however, is somewhat different; the lines generally are more exposed to wave loading and the configuration varies between the connected condition and the stand-off condition, posing extra requirements on the end connectors and bend stiffeners. The performance of these components should be evaluated carefully for dynamic jumper line applications.

4.3 FLEXIBLE PIPE DESCRIPTION—UNBONDED PIPE

This recommended practice does not apply to flexible pipes for use in choke and kill line or umbilical applications. See API Specification 16C for choke and kill line applications and API Specification 17E for umbilical applications.

4.3.1 General

4.3.1.1 An unbonded flexible pipe combines low bending stiffness with high axial tensile stiffness, which is achieved by a composite pipe wall construction. The two basic components are helical armoring layers and polymer sealing layers which allow a much smaller radius of curvature than for steel pipe with the same pressure capacity. Generally, a flexible pipe is designed specifically for each application and not an off-the-shelf product. This allows the pipe to be optimized for each application.

4.3.1.2 A typical cross-section of a flexible pipe is shown in Figure 6. The main layers identified are as follows:

a. Carcass: This is an interlocked metallic layer which provides collapse resistance. An example of a carcass profile shown in Figure 7.

b. Internal pressure sheath: This is an extruded polymer layer which provides internal fluid integrity.

c. Pressure armor: This is an interlocked metallic layer which supports the internal pressure sheath and system internal pressure loads in the radial direction. Some example profiles for the pressure armor wires are shown in Figure 7. A back-up pressure armor layer (generally not interlocked) also may be used for higher pressure applications.

d. Tensile armors: The tensile armor layers typically use flat, round, or shaped metallic wires, in two or four layers crosswound at an angle between 20 degrees and 60 degrees. The lower angles are used for pipe constructions, which include a pressure armor layer. Where no pressure armor layer is used, the tensile armor layers are crosswound at an angle close to 55 degrees to obtain a torsionally balanced pipe and to balance hoop and axial loads.

e. Outer sheath: This is an extruded polymer sheath, which provides external fluid integrity..

Table 1—Description of Standard Flexible Pipe Families—Unbonded Pipe

Layer No.	Layer Primary Function	Product Family I Smooth Bore Pipe	Product Family II Rough Bore Pipe	Product Family III Rough Bore Reinforced Pipe
1	Prevent collapse		Carcass	Carcass
2	Internal fluid integrity	Internal pressure sheath	Internal pressure sheath	Internal pressure sheath
3	Hoop stress resistance	Pressure armor layer(s)		Pressure armor layer(s)
4	External fluid integrity	Intermediate sheath		
5	Tensile stress resistance	Crosswound tensile armors	Crosswound tensile armors	Crosswound tensile armors
6	External fluid integrity	Outer sheath	Outer sheath	Outer sheath

Notes:
1. All pipe constructions may include various nonstructural layers, such as anti-wear layers, tapes, manufacturing aid layers, etc.
2. An external carcass may be added for protection purposes.
3. The pressure layer may be subdivided into an interlocked layer(s) and back-up layer(s).
4. The number of crosswound armor layers may vary, though generally is either two or four.
5. Thermal insulation may be added to the pipe.
6. The internal pressure and outer sheaths may consist of a number of sublayers.
7. Product family III is generally used for higher pressure applications than II.
8. The intermediate sheath for smooth bore pipes is optional when there is no external pressure or external pressure is less than the collapse pressure of the internal pressure sheath for the given application.

Table 2—Description of Standard Flexible Pipe Families—Bonded Pipe

Layer No.	Layer Primary Function	Product Family IV Smooth Bore Pipe	Product Family V Rough Bore Pipe
1	Prevent collapse		Carcass
2	Internal fluid integrity	Liner	Liner
3	Hoop and tensile stress resistance	Reinforcement armor(s)	Reinforcement armor(s)
4	External fluid integrity and protection	Cover	Cover

Notes:
1. All pipe construction may include various nonstructural layers, such as filler layers and breaker fabrics.
2. An external carcass may be added to product family V for protection purposes.
3. The number of crosswound reinforcement armors may vary, though generally is either two or four.

4.3.2 Classification of Flexible Pipe

4.3.2.1 Currently, unbonded flexible pipes can be generally classified into three distinct families. These classifications are identified in Table 1. The footnotes to Table 1 list the typical variations within these standard pipe design families. There are also distinctions within these families between pipes for static and dynamic applications, with the main distinction being the use of anti-wear layers for dynamic applications if they are required to achieve service life criteria.

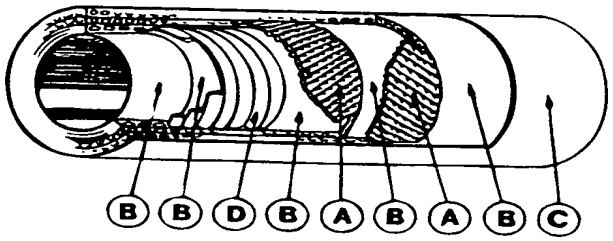
4.3.2.2 The classifications for bonded flexible pipe are identified in Table 2. Smooth bore flexible pipes (Product Families I and IV) are often used for water injection or dead crude applications

4.3.3 End Fittings

4.3.3.1 The terminations in a flexible pipe are described as end fittings. A typical end fitting is illustrated in Figure 8. End fittings may be built in during pipe manufacture or installed in the field. The purpose of a flexible pipe end fitting is twofold, namely:

a. To terminate all the strength members in the pipe's construction so that axial loads and bending moments can be transmitted into the end connector without adversely affecting the fluid-containing layers.

Bonded Flexible Pipe



A Reinforcement winding
B Fluid containing liner
C Outer jacket
D Structural members

Unbonded Flexible Pipe

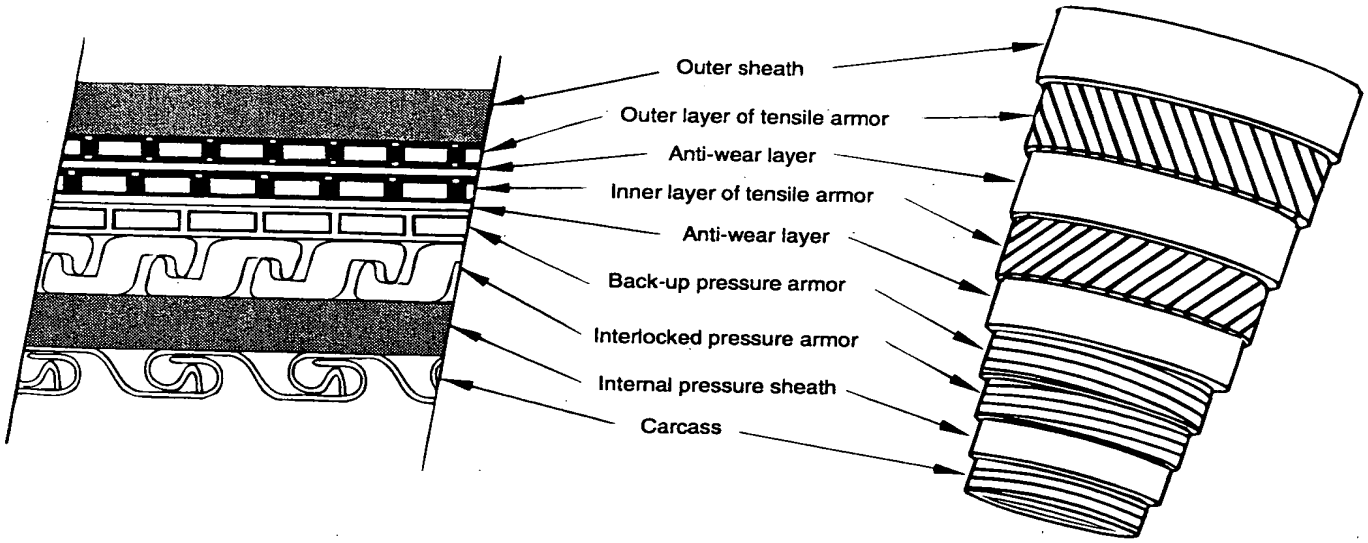


Figure 6—Schematic of Typical Flexible Riser Cross-sections